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Development of the food-based Lifelines Diet Score (LLDS) and its application in 129 369 Lifelines participants

Petra C. Vinke[1], Eva Corpeleijn[1], Louise H. Dekker[2], David R. Jacobs Jr[3], Gerjan Navis[2], Daan Kromhout[1]

[1]Department of Epidemiology, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

[2]Department of Nephrology, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

[3]Division of Epidemiology and Community Health, School of Public Health, University of Minnesota, Minneapolis, Minnesota, USA

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The authors declare no conflict of interest.

Correspondence:

Petra Vinke, MSc

University of Groningen, University Medical Center Groningen, Department of Epidemiology (FA40)

P.O. Box 30 001, 9700 RB Groningen, The Netherlands

p.c.vinke@umcg.nl

+31(0)50 - 3610583

Running title: Lifelines Diet Score: development and application

Abstract

Objective: Many diet quality scores exist, but fully food-based scores based on contemporary evidence are scarce. Our aim was to develop a food-based diet score based on international literature and examine its discriminative capacity and socio-demographic determinants.

Methods: Between 2006–2013, dietary intake of 129 369 participants of the Lifelines Cohort (42% male, 45±13 years (range 18-93)) was assessed with a 110-item food frequency questionnaire. Based on the 2015 Dutch Dietary Guidelines and underlying literature, nine food groups with positive (vegetables, fruit, whole grain products, legumes&nuts, fish, oils&soft margarines, unsweetened dairy, coffee and tea) and three food groups (red&processed meat, butter&hard margarines and sugar-sweetened beverages) with negative health effects were identified. Per food group, the intake in grams/1000 kcal was categorized into quintiles, awarded 0 to 4 points (negative groups scored inversely) and summed. Food groups with neutral, unknown or inconclusive evidence are described but not included.

Results: The Lifelines Diet Score (LLDS) discriminated well between high and low consumers of included food groups. This is illustrated by e.g. a 2-fold higher vegetable intake in the highest, compared to the lowest LLDS quintile. Differences were 5.5-fold for fruit, 3.5-fold for fish, 3-fold for dairy and 8-fold for sugar-sweetened beverages. The LLDS was higher in females and positively associated with age and educational level.

Conclusions and perspectives: The LLDS is based on the latest international evidence for diet-disease relations at the food group level and has high capacity to discriminate people with widely different intakes. Together with the population-based quintile approach, this makes the LLDS a flexible, widely applicable tool for diet quality assessment.

Introduction

The importance of nutrition in the development of non-communicable diseases and in the overall burden of disease has been well established. A recent development in this field is the focus on specific foods and dietary patterns. There is increasing evidence that foods and dietary patterns substantially affect chronic disease risk, whereas the relations with individual nutrients are less pronounced. (1,2) This superiority of foods and dietary patterns may in part be explained by the concept of food synergy, which underlines the additive or more than additive influence of foods and food constituents on health. (3)

Following these recent developments, many countries, including the United States, Australia and Nordic countries, now provide food-based dietary guidelines.(4) In the Netherlands, the Dutch Health Council issued their food-based dietary guidelines in 2015. The guidelines are the result of a systematic and critical evaluation of international peer-reviewed literature on relations of foods, dietary patterns and nutrients with causal risk factors and chronic disease risk.(1)

Worldwide, numerous dietary indices have been developed to measure adherence to dietary guidelines or dietary patterns, such as the Healthy Eating Index (HEI)(5,6) and the Mediterranean Diet Score (MDS)(7,8). Both scores were inversely associated with the risk of chronic diseases and all-cause mortality in prospective cohort studies.(8–10) However, the different versions of the HEI and the MDS are not completely food-based and in line with current scientific evidence. For example, besides food products, both scores also consider intake of saturated or unsaturated fatty acids. Furthermore, the MDS recommends low dairy intake although there is prospective cohort evidence for the inverse relation of milk with colorectal cancer, and yoghurt with diabetes. (11,12) In addition, the MDS does not include sugar-sweetened beverages of which detrimental effects on obesity and diabetes risk are well established.(13,14)

The present study aimed to develop a food-based diet quality score in accordance with the current international evidence on diet-disease relations, presented in the 2015 Dutch Dietary Guidelines. The score should be compatible with data obtained through common dietary assessment methods. The discriminative capacity of the diet score and its association with socio-demographic determinants was evaluated in the Lifelines Cohort, and the score was therefore named the Lifelines Diet Score (LLDS). The large Lifelines cohort, established in 2006, is a contemporary observational population-based cohort study and biobank in the Northern part of the Netherlands, including approximately 10% of the region's population. The overall aim of this resource is to gain insight into the etiology of healthy aging(15), and it therefore also covers nutrition.(16) A detailed description of food consumption in this cohort will be presented in this article.

Methods

Cohort design and study population

The Lifelines cohort study is a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviors of 167 729 persons living in the North of the Netherlands. It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioral, physical and psychological factors which contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. The overall design and rationale of the study have been described in detail elsewhere.(15,17) Participants were included in the study between 2006 and 2013, and written informed consent was obtained from all participants. Dietary information was available for 144 095 adults. The reliability of reported dietary intake was based on the Goldberg cut-off method, which relies on the ratio of reported energy intake and basal metabolic rate (18), calculated with the Schofield

equation.(19) 14 726 participants with a ratio below 0.87 or above 2.75 were excluded (<0.89 or >2.66 for participants >75 years), leaving 129 369 participants in the study. The LifeLines study is approved by the medical ethical committee of the University Medical Center Groningen, The Netherlands.

Data collection

Self-administered questionnaires were used to collect data regarding demographics (ethnicity, education) and lifestyle (smoking, alcohol, diet). Height and body weight without shoes and heavy clothing were measured at one of the Lifelines research sites, with the SECA 222 stadiometer and the SECA 761 scale. Body mass index (BMI) in kg/m^2 was calculated.

Dietary assessment

To assess dietary intake in the Lifelines Cohort, a 110-item semi-quantitative baseline food frequency questionnaire (FFQ) assessing food intake over the previous month was developed by Wageningen University using the Dutch FFQTOOL™, in which food items were selected based on the Dutch National Food Consumption Survey of 1997/1998.(20) The Lifelines FFQ was designed to include food groups that account for at least 80% of the variance and 80% of the population intake of both energy and macronutrients. Seven response categories were used to assess consumption frequency, ranging from 'not this month' to '6-7 days a week'. Portion size was estimated by fixed portion sizes (e.g. slices of bread, pieces of fruit) and commonly used household measures (e.g. cups, spoons). Energy and macronutrient intake was estimated from the FFQ data by using the Dutch food composition database of 2011.(21) Alcohol consumption was also estimated based on FFQ data.

2015 Dutch Dietary Guidelines

The food-based 2015 Dutch Dietary Guidelines represent an overview of the current internationally available scientific evidence on the relation of foods and dietary patterns with

chronic diseases.(1) The Dutch Health Council selected 10 major diet-related chronic diseases based on mortality, life-years lost and burden of disease in the Netherlands: coronary heart disease, stroke, heart failure, diabetes mellitus type 2, chronic obstructive pulmonary disease, breast cancer, colon cancer, lung cancer, dementia and depression. Three intermediate risk factors (systolic blood pressure, LDL-cholesterol, body weight) were considered because of their causal relation with coronary heart disease, stroke, heart failure or type 2 diabetes. The Council performed 29 systematic reviews of international peer-reviewed meta-analyses of prospective cohort studies and randomized controlled trials on relations of foods, dietary patterns and nutrients with these risk factors or chronic diseases risk were evaluated. In establishing the Guidelines, strength of available scientific evidence was considered. Evidence was considered strong when high quality meta-analyses were available and heterogeneity was either absent or could be explained. This procedure leads to evidence-based guidelines, as opposed to guidelines which are based on cultural preference or expert opinions.

Development of the Lifelines Diet Score

The 110 FFQ items were categorized into 22 food groups **(Supplementary Table 1)**. Based on the evidence provided by the Guidelines(1), the food groups were categorized as positive, negative, neutral or unknown. Nine positive groups (vegetables, fruit, whole grain products, legumes & nuts, fish, oils & soft margarines, unsweetened dairy, coffee and tea), one neutral group (eggs), three negative groups (red & processed meat, butter & hard margarines and sugar-sweetened beverages) and nine unknown groups for which evidence is either absent or weak (potatoes, refined grain products, white unprocessed meat, cheese, savory & ready products, sugary products, soups, sweetened dairy, artificially sweetened products) were identified **(Figure 1)**. The nine positive and three negative food groups were combined into the LLDS. An overview of the health effects of these food groups is presented in

Supplemental Table 2.

For the LLDS to represent relative diet quality, taking into account differences in energy intake between individuals, intake of the food groups was expressed in grams per 1000 kilocalories (kcal) instead of grams per day. For each food group, intake was divided into quintiles to score an individual's consumption compared to others in the study population. The quintiles ranged from 0 to 4, with 4 points being awarded to the highest quintile of consumption for positive food groups, and to the lowest quintile for negative food groups.(22–24) The sum of the 12 component scores resulted in a LLDS score ranging from zero to 48. Sensitivity analysis was performed to investigate whether gender stratification as an alternative for energy adjustment, would categorize participants similarly.

Data analysis

The average intake of energy (kcal), carbohydrates, fat and protein (energy%) were calculated. Food group consumption in grams/1000 kcal was calculated and presented in medians and interquartile ranges, because of the skewed distribution of the majority of the food groups. Participant characteristics and food group consumption were presented stratified by age (18-40, 40-59, $\geq$ 60 years) and gender to get more insight into the subpopulations of the cohort. Median consumption per component was presented across quintiles of the LLDS, separately for men and women. Furthermore, mean LLDS scores were visualized, stratified by gender, age and educational level. Correlations between components of the LLDS were assessed to ensure the independent contribution of all components to the score.

The chances of rejecting the null hypothesis with negligible differences is high in a population-based cohort study of 129 369 participants, so p-values were not included in this paper.(25) Data analysis was performed in IBM SPSS 23 (SPSS, Chicago Illinois, USA).

Results

This study included 129 369 participants (41.5% males, 58.5% females) with a mean age of 44.8 (SD = 13.1, range 18-93). **Table 1** shows an inverse relationship between educational level and the three age groups, especially in women. Mainly in men, energy intake was lower in higher age groups. Contributions of macronutrients to total energy intake were comparable between groups. Body Mass Index (BMI) and the prevalence of obesity was higher in older age groups. The percentage of current smokers and alcohol users was lower in higher age groups.

Food groups

The median consumption per food group in grams/1000 kcal shows that consumption of the food groups differs by gender and age (**Table 2**). For example, the female diet was characterized by a higher intake of vegetables, fruit, unsweetened dairy and tea, whereas intake for sugar-sweetened beverages was higher for men. In the higher age groups, consumption was higher for vegetables, fruit, unsweetened dairy, coffee, tea and potatoes, while it was lower for sugar-sweetened beverages, savory & ready products and artificially sweetened products.

Lifelines Diet Score

The LLDS ranged from 1 to 46 in men (mean 22.6, SD 5.70) and from 3 to 46 in women (mean 25.0, SD 6.09). The correlation between components ranged from r=0.005 between tea and legumes & nuts, to r=0.364 between tea and coffee, explaining up to a maximum of 13% of variance. Cross-classification of energy adjusted scores to gender-stratified scores showed that 91.5% of participants was categorized in the same or adjacent quintile. Only 0.02% was categorized in extreme quintiles. Median consumption of the included food groups across quintiles of the total score are presented in **Table 3**, for men and women separately. In the

192 total study population, intake of positive components in the highest quintile was between 1.5
193 times (whole-grain products) and 6 times (tea) higher than in the lowest quintile. For the
194 negative components, intake in the highest quintile was between 8 times (sugar-sweetened
195 beverages) and 1.5 times (red & processed meat) lower than intake of the lowest quintile. The
196 LLDS was higher in women and positively associated with age category and educational level
197 (**Figure 2**). For men, mean LLDS ranged from 19.5 (SD = 5.30) in males aged below 40 with
198 low educational level, to 25.9 (SD = 5.50) in highly educated males aged 60 or higher. For
199 women, this range is 20.8 (SD = 5.74) to 29.1 (SD = 5.61).

200 ## Discussion

201 The food-based LLDS is a tool to rank participants on relative diet quality and is based on
202 solid contemporary evidence on diet-disease relationships. The large differences in
203 consumption of the included positive and negative food groups over quintiles of the LLDS
204 demonstrate its discriminative capacity. The LLDS was higher in women and positively
205 associated with age and educational level. The international literature underlying the LLDS,
206 together with the population-based quintile approach, make the LLDS an internationally
207 applicable tool to rank individuals on diet quality.

208 Although many diet scores exist, the current emphasis on food-based analyses created
209 the need for a fully food-based diet score in line with contemporary evidence. In the
210 development of the LLDS, nine positive, three negative, one neutral and nine unknown food
211 groups were identified based on the evidence from the 2015 Dutch Dietary Guidelines and its
212 underlying literature. (1) Analysis of the intake of these food groups in the Lifelines Cohort,
213 revealed gender and age specific dietary patterns. For example, the female diet was high in
214 vegetables, fruit and tea, whereas the male diet consisted of higher amounts of sugar-
215 sweetened beverages and oils & soft margarines. Higher consumption of potatoes and several
216 positive food groups, and lower sugar-sweetened beverage and artificially sweetened product

consumption characterized the diet of the elderly. This food consumption in the Lifelines population is in agreement with consumption reported in the Dutch National Food Consumption Survey (DNFCS) 2007-2010 (26), which is considered representative for the Netherlands.

The LLDS scored individuals on diet quality, by ranking their relative consumption of positive and negative food groups. All food groups contributed independently to the LLDS, indicated by the weak correlations between the groups. Comparing the quintiles of the LLDS, the range of consumption varied widely for all food groups, demonstrating good discriminative capacity. The wide range of consumption between the quintiles also emphasizes that there is room for improvement. For example, vegetable intake differed 2-fold between the lowest and highest LLDS quintile. Differences were 5.5-fold for fruit, 3.5-fold for fish, 3-fold for dairy and 8-fold for sugar-sweetened beverages. At the individual level, the room for improvement depends on how an individual's score is built up. To illustrate, a median score of 24 could indicate intermediate consumption of all food groups (e.g. two points awarded to all 12 components) leaving some room for improvement for all components, or a large room for improvement for some (e.g. zero points awarded to six components), but no improvement for other food groups (e.g. four points awarded to the other six components).

A relative approach rather than classification of absolute intake using pre-defined cut-offs was chosen to calculate the LLDS. This approach scored an individual's consumption of the included food groups, compared to others in the study population. Comparable to the A Priori Diet Quality Score(3,24), quintiles rather than medians or tertiles were used to score intake, to better approximate a diet quality continuum. Because of the relative quintile approach, the LLDS depends on the population characteristics, which makes it flexible for use in other populations. Furthermore, the use of quintiles rather than pre-defined cut-offs allows a level

of uncertainty in the intake estimates of the included food groups. This makes the LLDS approach compatible with data obtained through varying dietary assessment methods. A limitation of this approach is that comparison of scores across studies is difficult, since cut-offs are population-dependent. Reporting the intake of components per quintile of the LLDS can provide insight into differences across studies.

Expressing food intake in grams per 1000 kcal prevented the score from favoring those with higher overall food consumption, and measures the relative contribution of the positive and negative food groups to the total diet. An alternative for energy adjustment is ranking intake in gender-specific quintiles, as this will also adjust for a great part of variation in energy intake. The strong agreement in classification according to the two approaches suggests that gender-stratification may be a suitable alternative when proper estimation of energy intake is not possible. For example, this could be the case for short dietary screeners that substitute extensive FFQs, for which there is an upcoming interest (27,28).

The LLDS was higher in women and positively associated with age and educational level. Other dietary quality scores, such as the Healthy Eating Index, the Alternate Healthy Eating Index, Mediterranean Diet Score and A Priori Diet Quality Score have all shown similar associations with educational level (29–33), sex (30,32,34) and age (30,34). This shows that the association of the LLDS with socio-demographic determinants is comparable to those found for other widely used diet quality scores.

The Guidelines recommend the consumption of filtered coffee because unfiltered coffee increases LDL-cholesterol in controlled dietary experiments. (35) However, in prospective cohort studies, coffee consumption, independent of the type of coffee, was associated with lower risk of coronary heart disease, stroke, cardiovascular diseases and type 2 diabetes.(36,37) Combined with the methodological constraint that most dietary assessment methods do not distinguish between the type of coffee, we decided to include all types of

coffee in the LLDS.

Legumes and nuts were combined in one food group. A meta-analysis of prospective cohort studies showed that nut consumption was associated with lower coronary heart disease risk(38). The Dutch Health Council rated the evidence for the effect of legumes on coronary heart disease risk as less reliable, which would favor separating legumes and nuts. However, groups were combined because both are rich in plant-based protein and meta-analyses showed that both reduced LDL-cholesterol.(39,40) Also, combining the groups was expected to enhance discriminative power because consumption of both groups is low.

The Lifelines FFQ does not distinguish between whole grain and refined cereal products. In the Netherlands, whole meal and brown bread account for approximately 70% of bread consumption and with an estimated mean intake of 95 grams per day, it is the largest contributor to total whole grain consumption in the Netherlands.(41) Therefore, bread consumption was used as a proxy for whole grain consumption in this study. The remaining cereal products included in the FFQ (crackers/biscuits, croissants & other bread-rolls, breakfast cereals, pasta and rice) were classified as refined grain products as the Dutch population predominantly consumes refined variants of these items.(41) Alcoholic beverage consumption was not included in the LLDS as it was considered a lifestyle factor, rather than a food group.

In conclusion, the LLDS is a flexible tool to rank individuals on relative diet quality. This fully food-based score is in line with the recent international literature which was critically reviewed in the 2015 Dutch Dietary Guidelines, making the LLDS a tool of international relevance. Application of the LLDS in the contemporary Lifelines cohort showed that the score was higher in women and positively associated with age and educational level. The LLDS can be calculated with data derived through different dietary

assessment methods, but adaptation of the calculation method is desired when available data is not sufficient to estimate energy intake.

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Conflict of interest

The authors declare no conflict of interest.

Supplementary information is available at *European Journal of Clinical Nutrition's* website.

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434 **Figure 1:** Overview of the food groups.

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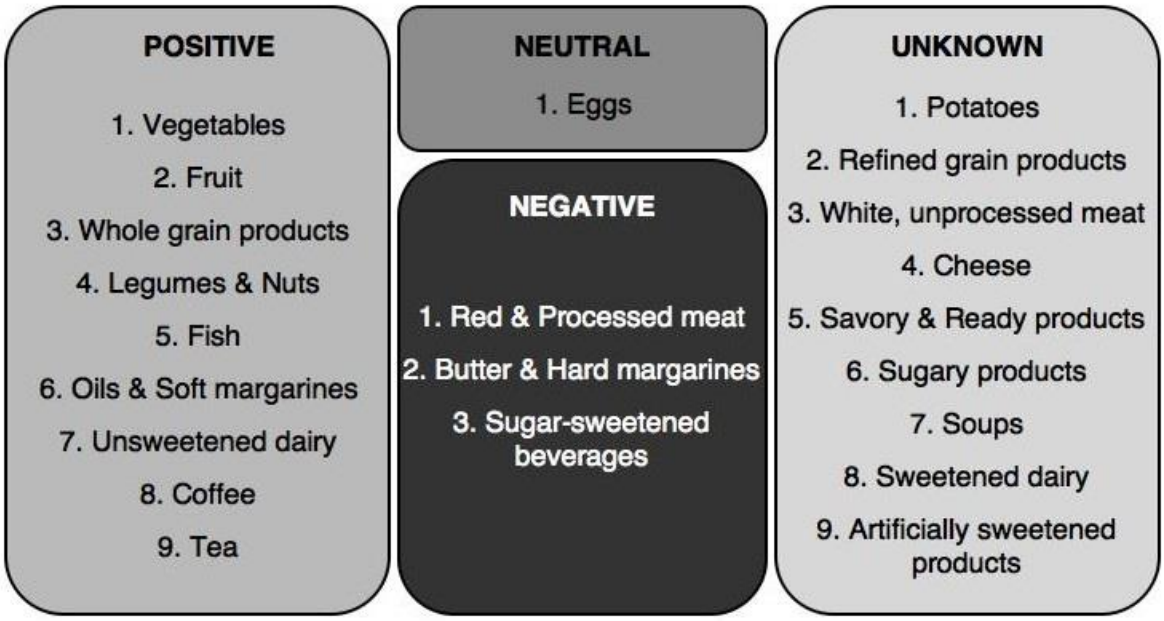

436 **Table 1:** Baseline data of the adult LifeLines population (N=129 369), collected between
437 2006 and 2013.

	Male			**Female**		
	18-39 years *(N=17360)*	40-59 years *(N=27369)*	≥ 60 years *(N=8923)*	18-39 years *(N=26196)*	40-59 years *(N=39039)*	≥ 60 years *(N=10482)*
DEMOGRAPHICS						
Age (years) (mean ± SD)	30.9 ± 5.8	47.9 ± 5.2	66.3 ± 5.2	30.2 ± 6.2	47.9 ± 5.2	65.8 ± 5.0
White, East/West European Ethnicity (%)	97.8	98.4	98.9	97.2	98.0	98.7
Education* (%)						
Low	18.2	31.2	44.5	13.8	31.1	64.7
Moderate	46.3	37.8	25.3	47.1	42.5	18.5
High	35.5	30.9	30.3	39.1	26.4	16.8
DIET						
Energy intake (kcal/day) (mean ± SD)	2511 ± 682	2395 ± 646	2093 ± 536	1863 ± 485	1851 ± 477	1718 ± 422
Percentage energy from[§]: (mean ± SD)						
Carbohydrates	48.0 ± 5.3	46.9 ± 5.4	46.4 ± 5.6	48.4 ± 5.5	46.5 ± 5.7	46.9 ± 5.8
Protein	14.9 ± 2.2	15.3 ± 2.2	15.9 ± 2.3	15.2 ± 2.4	16.1 ± 2.5	16.7 ± 2.5
Fat	37.1 ± 5.1	37.8 ± 5.1	37.7 ± 5.1	36.4 ± 5.0	37.4 ± 5.2	36.4 ± 5.2
LIFESTYLE						
Body Mass Index (kg/m^2) (mean ± SD)	25.3 ± 3.7	26.8 ± 3.6	27.0 ± 3.3	24.8 ± 4.6	26.1 ± 4.7	27.0 ± 4.3
Obesity[#] (%)	9.9	16.5	16.5	12.5	17.5	20.9
Alcohol						
User percentage (%)	92.1	90.6	89.0	78.5	77.0	74.3
Median consumption† (g/day)	8.8 [3.8 – 16.1]	8.6 [3.4 – 16.5]	9.0 [3.5 – 17.3]	3.2 [1.6 – 6.8]	5.3 [1.7 – 9.9]	6.1 [1.7 – 11.4]
Smoking (%)						
Current Smoker	29.6	21.9	12.2	23.7	19.5	8.8
Former Smoker	18.0	34.2	63.6	18.8	37.0	47.2
Never Smoker	52.4	43.9	24.2	57.6	43.5	44.0

* Low education = primary school, vocational and lower general secondary education. Moderate education = higher secondary education and intermediate vocational training. High education = higher vocational education and university education.

[#] Body mass index ≥ 30 kg/m^2

†Median + IQR among alcohol users. One standard drink contains 10g alcohol.

[§] Energy from carbohydrates, protein and fat, relative to the sum of energy from the three macronutrients.

438 **Table 2:** Median [p25-p75] consumption of the 22 food groups in the adult LifeLines
439 population (N=129 369) in grams per 1000 kcal, presented stratified by age and gender.

	Male			**Female**		
	18-39 years	40-59 years	≥ 60 years	18-39 years	40-59 years	≥ 60 years
Positive food groups						
Vegetables	35 [22 - 52]	39 [25 - 57]	48 [32 - 66]	49 [32 - 71]	56 [38 - 79]	63 [44 - 86]
Fruit	32 [11 - 65]	40 [16 - 80]	73 [37 - 117]	54 [24 - 102]	67 [31 - 119]	120 [70 - 166]
Whole grain products	58 [41 - 76]	58 [41 - 75]	57 [42 - 72]	51 [34 - 67]	51 [35 - 66]	55 [40 - 69]
Legumes & Nuts	8 [4 - 14]	10 [5 - 16]	10 [5 - 17]	7 [3 - 12]	8 [4 - 15]	9 [4 - 15]
Fish	4 [1 - 6]	5 [2 - 7]	6 [3 - 10]	5 [1 - 8]	6 [2 - 9]	7 [4 - 12]
Oils & soft margarines	9 [3 - 16]	9 [3 - 16]	6 [1 - 14]	8 [3 - 14]	7 [2 - 14]	4 [1 - 12]
Unsweetened dairy	57 [22 - 110]	66 [28 - 119]	83 [41 - 136]	66 [23 - 127]	83 [35 - 147]	102 [50 - 164]
Coffee	167 [77 - 253]	230 [156 - 318]	226 [161 - 304]	98 [0 - 213]	228 [141 - 325]	244 [170 - 327]
Tea	29 [5 - 84]	40 [5 – 102]	88 [19 - 162]	135 [53 – 253]	131 [48 – 243]	163 [73 – 269]
Neutral food groups						
Eggs	4 [2 - 8]	5 [3 - 8]	7 [3 - 10]	4 [3 - 8]	5 [3 - 9]	7 [4 - 11]
Negative food groups						
Red & processed meats	32 [24 - 42]	32 [24 - 42]	33 [23 - 43]	33 [23 - 43]	33 [23 - 43]	31 [20 - 42]
Butter & hard margarines	9 [3 - 16]	12 [6 - 19]	16 [9 - 24]	8 [3 - 15]	10 [5 - 18]	14 [7 - 21]
Sugar-sweetened beverages	82 [38 - 146]	49 [17 - 96]	27 [6 - 66]	65 [22 - 15]	32 [8 - 81]	16 [0 - 56]
Unknown food groups						
Potatoes	27 [13 - 43]	32 [19 - 49]	42 [26 - 60]	27 [13 - 43]	30 [17 - 46]	38 [23 - 55]
Refined grain products	34 [22 – 52]	34 [22 - 50]	27 [17 – 41]	37 [25 – 53]	36 [25 – 51]	27 [18 – 40]

	White, unprocessed meat	4 [3 - 7]	4 [2 - 6]	4 [2 - 6]	6 [3 - 9]	5 [3 - 8]	5 [2 - 8]
	Cheese	9 [4 - 16]	12 [6 - 19]	15 [9 - 23]	10 [5 - 17]	14 [8 - 22]	17 [11 - 26]
	Savory & Ready products	52 [37 - 71]	42 [28 - 58]	24 [14 - 38]	52 [37 - 70]	41 [27 - 57]	22 [13 - 36]
	Sugary products	32 [22 - 44]	35 [23 - 48]	37 [25 - 51]	38 [26 - 51]	37 [24 - 50]	38 [26 - 52]
	Soups	15 [8 - 28]	17 [10 - 33]	19 [11 - 37]	16 [10 - 27]	18 [11 - 32]	19 [12 - 35]
	Sweetened dairy products	38 [19 - 62]	39 [20 - 60]	46 [23 - 70]	44 [21 - 72]	43 [20 - 69]	52 [25 - 80]
	Artificially sweetened products	11 [0 - 49]	8 [0 - 43]	3 [0 - 27]	21 [0 - 75]	12 [0 - 69]	3 [0 - 31]

444 **Table 3:** Median [p25-p75] consumption of the 12 components included in the LifeLines Diet
445 Score in grams per 1000 kcal, per quintile of the LLDS for men and women separately.

	Quintiles of LLDS					
	Males			Females		
	1	**3**	**5**	**1**	**3**	**5**
	(N=13.137)	(N=10.336)	(N=6.233)	(N = 11.098)	(N = 14.108)	(18.038)
LLDS-score*	16 [1 - 18]	24 [23 – 25]	32 [30 – 46]	16 [3 – 18]	24 [23 – 25]	32 [30 – 46]
Energy intake (kcal) #	2597 ± 719	2350 ± 617	2064 ± 521	2023 ± 531	1872 ± 461	1659 ± 397
Positive components						
Vegetables	29 [18 – 41]	42 [28 – 58]	60 [43 – 81]	36 [23 – 51]	52 [36 – 71]	76 [56 – 99]
Fruit	17 [6 – 39]	48 [23 – 86]	93 [56 – 133]	25 [9 – 49]	62 [33 – 107]	123 [80 – 165]
Whole grain products	47 [11 – 63]	61 [45 – 76]	71 [55 – 86]	40 [27 – 55]	51 [36 – 65]	61 [44 – 76]
Legumes & Nuts	6 [2 – 10]	10 [5 – 16]	15 [9 – 22]	4 [2 – 8]	7 [4 – 13]	12 [6 – 19]
Fish	3 [0 – 5]	5 [2 – 7]	8 [5 – 12]	2 [0 – 5]	5 [2 – 8]	9 [6 – 13]
Oils & soft margarines	5 [2 – 11]	10 [3 – 17]	13 [6 – 18]	5 [2 – 10]	7 [2 – 13]	10 [3 – 16]
Unsweetened dairy	38 [13 – 77]	73 [35 – 123]	109 [64 – 164]	36 [11 – 80]	77 [33 – 135]	119 [66 – 182]
Coffee	164 [87 – 246]	221 [147 – 308]	257 [185 – 343]	117 [0 – 218]	189 [83 – 283]	254 [165 – 347]
Tea	13 [0 – 56]	46 [8 – 109]	113 [44 – 194]	60 [12 – 143]	129 [51 – 230]	213 [121 – 325]
Negative components						
Red & processed meat	37 [28 – 46]	32 [24 – 41]	25 [17 – 34]	37 [28 – 47]	34 [24 – 44]	26 [16 – 36]
Butter, hard margarines	16 [9 – 23]	11 [5 – 17]	5 [1 – 11]	16 [9 – 22]	11 [5 – 18]	5 [1 – 11]
Sugar-sweetened beverages	104 [54– 170]	46 [17 – 87]	18 [4 – 45]	120 [62 – 196]	44 [13 – 91]	13 [0 – 36]

* Median score + Full Range

Mean + SD

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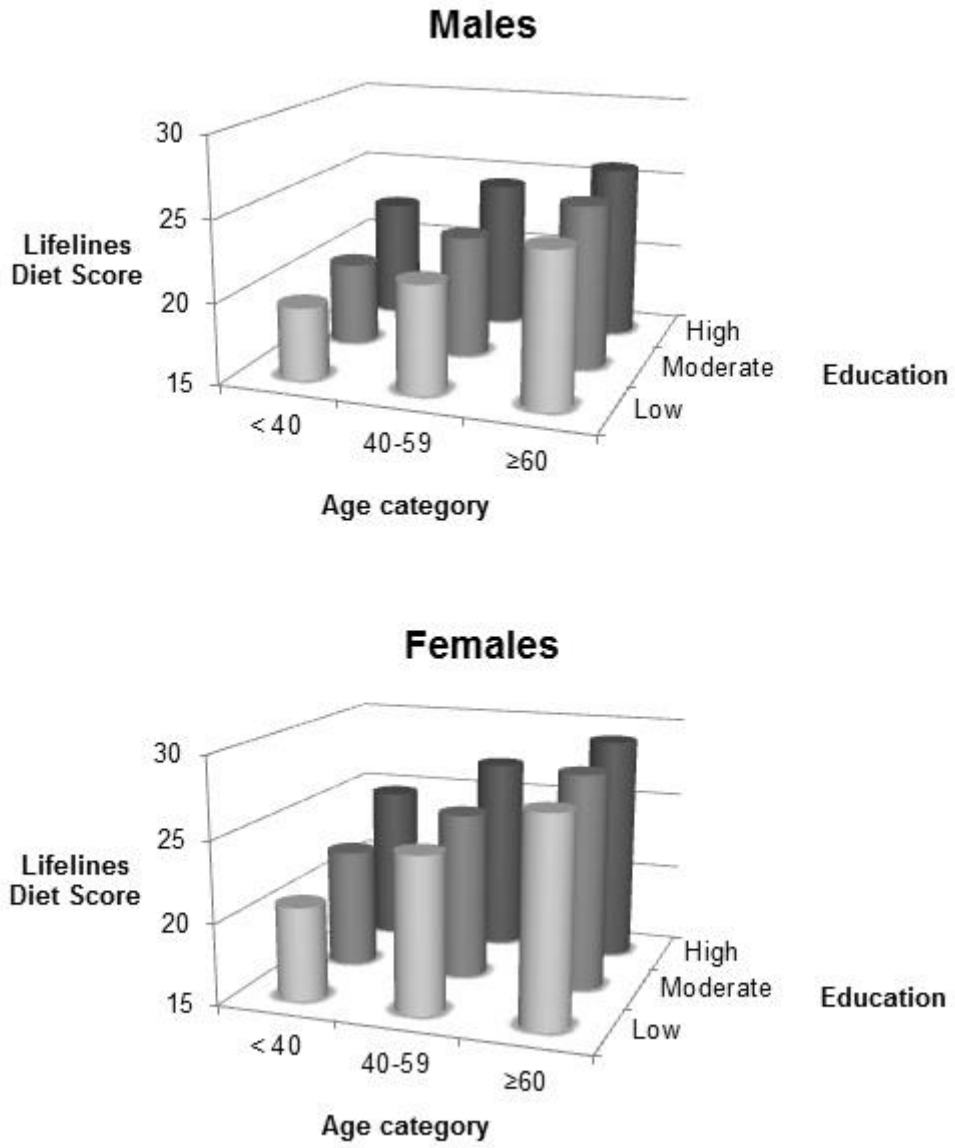
447

448 **Figure 2:** Mean Lifelines Diet Score, stratified by age category and educational level.



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450 * Low education = primary school, vocational and lower general secondary education.
451 Moderate education = higher secondary education and intermediate vocational training.
452 High education = higher vocational education and university education.

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Supplementary Tables

Table S1: Classification of FFQ items in the 22 established food groups, including comments regarding the choices that have been made.

Group	Examples of food group items	LL FFQ items	Comments
Positive food groups			
Vegetables	All boiled, stir-fried and raw vegetables (fresh, canned or frozen)	Boiled vegetables with butter, boiled vegetables without butter, stir-fried vegetables (including vegetables in mixed dishes)	Vegetables prepared with butter or cream are also included in this group since there is no evidence that these additions abolish the positive effects of vegetable consumption. However, the consumption of vegetables without cream or butter is recommended.
Fruit	All whole fruits (fresh or frozen)	Fresh fruit	Fruit juices are included in sugar-sweetened beverages. Canned fruit in syrup and apple sauce are included in the group sugary products due to high amounts of added sugars.
Whole grain products	Whole grain crackers/biscuits, bread rolls, slices of bread, breakfast cereals, pasta and brown rice. Products should contain at least 25% wholegrain flour	Slices of bread	The LifeLines FFQ does not distinguish between whole grain and refined products. In the Netherlands, whole meal and brown bread account for approximately 70% of bread consumption. Also, with an estimated mean intake of 95 grams per day, whole meal and brown bread are the largest contributors to the total whole grain consumption in the Netherlands. Therefore, bread was used as a proxy for whole grain consumption.

Legumes & Nuts	Plant-based, protein rich products including nuts, legumes and seeds	Legumes, nuts or seeds with a meal, nuts as snack, peanut butter	Salted nuts and salt-containing peanut butter are also included in this group since there is no evidence that this addition abolishes the positive effects of nut consumption. Peanut butter is included because peanuts are the main ingredient.
Fish	All types of fish	Herring, fried fish, lean fish, fatty fish, other kinds of fish	All types of fish are included in this group since there is no evidence that frying or adding salt to fish abolishes the positive effects of fish consumption. Furthermore, lean types of fish are included since total fish consumption also has beneficial effects.
Oils & Soft margarines	Plant-based oils, spreads, soft margarines and other soft/liquid baking fats	Margarine spread for bread, salad dressing, mayonnaise	Salad dressing and mayonnaise are included in this group since plant-based oils are the main ingredient of these items.
Unsweetened dairy	All unsweetened milk and yoghurt products	Semi-skimmed milk, low-fat milk, buttermilk, low-fat yoghurt, full-fat yoghurt, milk in coffee	No distinction is made between low and high fat dairy, since there is evidence for health benefits of total dairy consumption. Due to high sugar content of sweetened dairy products, the Health Council advised to avoid sweetened dairy.
Coffee	Coffee	Coffee	Both coffee consumed with and without sugar are included in this group, since health benefits for coffee are found for total consumption and not for coffee consumption without sugar alone. However, the consumption of coffee without sugar is recommended.
Tea	Green or black tea	Tea	Both tea consumed with and without sugar are included in this

			group, since health benefits for tea are found for total consumption and not consumption for tea without sugar alone. However, the consumption of tea without sugar is recommended.
Neutral food groups			
Eggs	Boiled or fried eggs, omelets	Boiled eggs, fried eggs	Eggs used in combination dishes (hot meals, baked goods) are not included in this group.
Negative food groups			
Red & Processed meat	Red and processed meat, including deli meat	Deli meat, several types of beef and pork, both processed and unprocessed	Red and processed meat are both included in this group, since health effects described in literature usually concern both the consumption of red and processed meat.
Butter & Hard margarines	All types of butter and hard margarines	Butter/Margarine on bread, other spreads on bread, gravy	Butter and hard margarines used for cooking as well as on sandwiches are included in this group. Gravy is included in this group as butter and hard margarines are usually the main component.
Sugar-sweetened beverages	All types of sugar containing drinks	Breakfast drinks, soda or lemonade with sugar, fruit-drinks, fruit juice, alcohol-free beers	Fruit juice are included in this group because effects of fruit in liquid form are assumed equal to those of other sugary drinks. Sugar-containing light fruit-drinks are also included in this group, but sugar-free artificially sweetened drinks are not.
Unknown food groups			
Potatoes	Boiled and mashed potatoes	Boiled potatoes, mashed potatoes	French fries, fried potatoes and potato chips are included in savory, ready products because of their high fat and salt content.
Refined cereal products	Crackers/biscuits, bread rolls, slices of bread, breakfast	Crackers/biscuits, croissants & other bread rolls, breakfast	Refined cereal products are a less healthy choice compared with whole grain products. The health

	cereals, pasta and rice that contain less than 25% whole grain flour	cereals, pasta and rice	effects of refined cereal products are unclear. In the Netherlands, the majority of breakfast cereals, crisp breads & rusks, rice and pasta consumed concern refined grain variants (approximately 55%, 60%, 85% and 95%, respectively). These items are included in this group, as the LifeLines FFQ does not distinguish between refined and whole grain variants of the items.
White, unprocessed meat	Chicken filets, turkey filets	chicken without skin, chicken with skin	This group does not include fried chicken, which is included in savory, ready products because of the high fat and salt content.
Cheese	All cheeses, low and high fat	20/30% fat cheese, 40% fat cheese, 48% fat cheese, cream cheese	Both low and high fat cheeses are included in this group. The contribution of low-fat cheese to total cheese consumption is marginal.
Savory & Ready products	All ready products, including both snacks and ready meals	Asian ready meals, fast food, pizza, warm sauces, warm fried snacks, potato chips, French fries	This group mainly consists of products that are high in (satiated) fat and salt. The composition of the products is usually unknown and varying. The health effects of this group are unclear.
Sugary products	Sandwich spreads, candy, biscuits, cakes or chocolates	Chocolate sandwich spread, other sweet sandwich spreads, sugar or syrup in coffee/tea, small biscuits, cake or large cookies, pies, candy bars, chocolate, candy, applesauce	This group mainly consists of products that are high in sugar and/or (satiated) fat. The composition of the products is often unknown and strongly varying and the health effects of this group as a whole are unclear.
Soups	All soups	Soups with legumes, soups without legumes	The composition of soups consumed is usually unknown. Although usually high in salt, vegetables could be a main ingredient, especially of home-made soups.

Sweetened dairy	Sweetened yoghurts, ice-cream, custard, sweetened dairy drinks	Fruit yoghurts, custard, ice-cream with dairy, whipped cream, vanilla yoghurt, chocolate milk, sweetened yoghurt drinks	It is unknown whether the added sugar abolishes the effects of the nutrient rich dairy.
Artificially sweetened products	Light soda's, artificially sweetened dairy products	Light soda, light lemonade, artificially sweetened yoghurt drinks	There is yet no consensus on the health effects of artificially sweetened products, both drinks and solid foods.

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Table S2: Overview of food groups included in the LifeLines Diet Score and known associations with specific chronic diseases and causal risk factors. Green cells indicate strong evidence for a positive association between consumption and the disease/risk factor, red cells indicate a negative association. Overview based on the 2015 Dutch Dietary Guidelines[1] and its background documents[2]. An * indicates that the health effect only concerns a subgroup of the food group.

	Coronary heart disease	**Stroke**	**T2DM**	**Colon cancer**	**Lung cancer**	*Systolic blood pressure*	*LDL-cholesterol*	*Body weight*
Vegetables			** green leafy vegetables*		** green leafy vegetables*			
Fruit								
Whole grain products							**oats*	
Legumes & Nuts	**nuts*							
Fish								
Oils & soft margarines	**MUFA*							
Unsweetened dairy			** yoghurt*	** milk, total dairy*				**extra ad libitum dairy*
Coffee							**unfiltered coffee*	
Tea							**green tea*	
Red & processed meat					** red meat*			
Butter & Hard margarines	**SFA*						** butter*	
Sugar-sweetened beverages								

1. Kromhout D, Spaaij CJK, de Goede J, Weggemans RM. The 2015 Dutch food-based dietary guidelines. Eur J Clin Nutr. 2016;70:869–78.
2. Health Council of the Netherlands. Methodology for the evaluation of the evidence for the Dutch dietary guidelines 2015 - Background document Dutch dietary guidelines 2015. The Hague: Health Council of the Netherlands, 2015; publication no. A15/03E. ISBN 978-94-6281-067-9